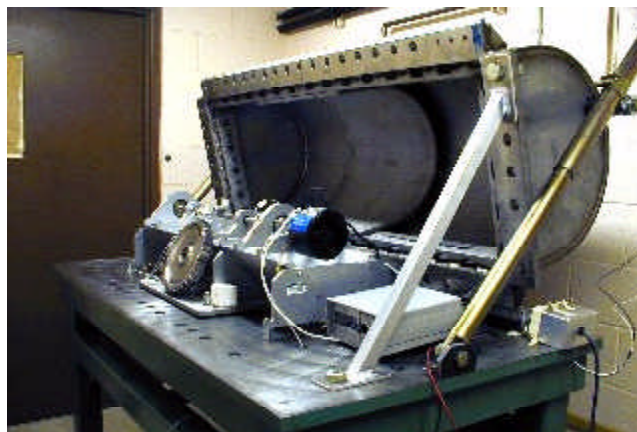


# Vibration-Based Data Used to Detect Cracks in Rotating Disks

Rotor health monitoring and online damage detection are increasingly gaining the interest of aircraft engine manufacturers. This is primarily due to the fact that there is a necessity for improved safety during operation as well as a need for lower maintenance costs. Applied techniques for the damage detection and health monitoring of rotors are essential for engine safety, reliability, and life prediction. Recently, the United States set the ambitious goal of reducing the fatal accident rate for commercial aviation by 80 percent within 10 years (ref. 1). In turn, NASA, in collaboration with the Federal Aviation Administration, other Federal agencies, universities, and the airline and aircraft industries, responded by developing the Aviation Safety Program. This program provides research and technology products needed to help the aerospace industry achieve their aviation safety goal. The Nondestructive Evaluation (NDE) Group of the Optical Instrumentation Technology Branch at the NASA Glenn Research Center is currently developing propulsion-system-specific technologies to detect damage prior to catastrophe under the propulsion health management task.

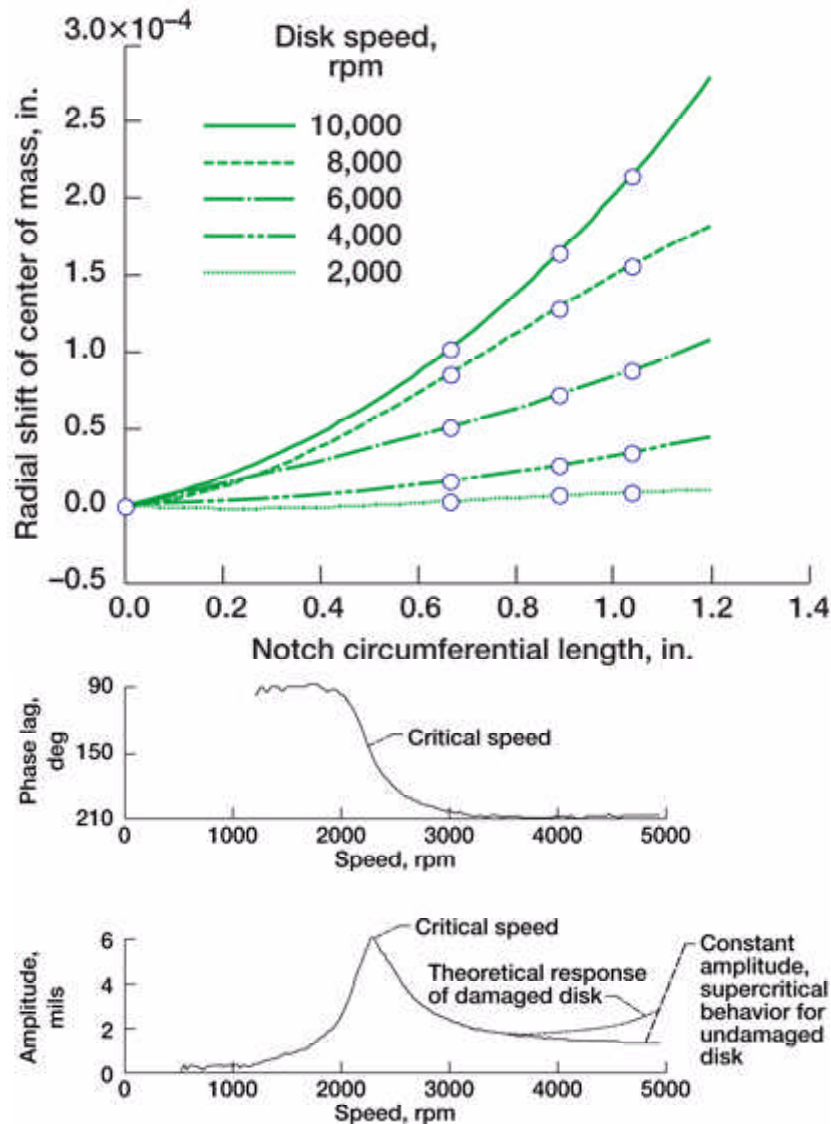
Currently, the NDE group is assessing the feasibility of utilizing real-time vibration data to detect cracks in turbine disks. The data are obtained from radial blade-tip clearance and shaft-clearance measurements made using capacitive or eddy-current probes. The concept is based on the fact that disk cracks distort the strain field within the component. This, in turn, causes a small deformation in the disk's geometry as well as a possible change in the system's center of mass. The geometric change and the center of mass shift can be indirectly characterized by monitoring the amplitude and phase of the first harmonic (i.e., the  $1\times$  component) of the vibration data. Spin pit experiments and full-scale engine tests have been conducted while monitoring for crack growth with this detection methodology (ref. 2). Even so, published data are extremely limited, and the basic foundation of the methodology has not been fully studied.



*Subscale disk spin simulation system.*

The NDE group is working on developing this foundation on the basis of theoretical

modeling as well as experimental data by using the newly constructed subscale spin system shown in the preceding photograph. This, in turn, involved designing an optimal sub-scale disk that was meant to represent a full-scale turbine disk; conducting finite element analyses of undamaged and damaged disks to define the disk's deformation and the resulting shift in center of mass; and creating a rotordynamic model of the complete disk and shaft assembly to confirm operation beyond the first critical concerning the subscale experimental setup. The finite element analysis data, defining the center of mass shift due to disk damage, are shown in the top figure. As an example, the change in the center of mass for a disk spinning at 8000 rpm with a 0.963-in. notch was  $1.3 \times 10^{-4}$  in. The bottom figure shows the actual vibration response of an undamaged disk as well as the theoretical response of a cracked disk.



Top: Radial shift of the center of mass as a function of notch length and disk revolutions per minute. Bottom: Experimental vibration response of the  $1 \times$  component. Also indicated is the theoretical response of a damaged disk.

Experiments with cracked disks are continuing, and new approaches for analyzing the captured vibration data are being developed to better detect damage in a rotor. In addition, the subscale spin system is being used to test the durability and sensitivity of new NDE sensors that focus on detecting localized damage. This is designed to supplement the global response of the crack-detection methodology described here.

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